Unemployment and innovation patterns: the role of business coordination and market competition

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The role of business coordination
and market competition

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Abstract

The paper explores the institutional determinants of differences in European, Japanese and American unemployment and innovation pattern in a „comparative institutional analysis“ perspective. Building on the definition of different modes of coordination among firms, the question is addressed as to how institutional settings affect firms’ innovation strategy. A generalized efficiency wage model is developed determining both equilibrium unemployment and innovation. The mode of coordination is shown to affect firms’ choice between radical and incremental innovations as well as firms’ response (in terms of innovation strategy) to increased competitive pressure. Higher unemployment may result as a consequence of specialization along innovation trajectories.

Zusammenfassung

In diesem Diskussions-Papier wird untersucht, welchen Einfluß institutionelle Determinanten auf die unterschiedlichen Muster von Arbeitslosigkeit und Innovation in Europa, in Japan und in den USA haben. Dies geschieht durch eine „vergleichende Institutionen-Analyse“. Ausgehend von unterschiedlichen Formen der Koordination zwischen Unternehmen ist die Analyse auf die Frage gerichtet, wie institutionelle Rahmenbedingungen die Entscheidung für eine bestimmte Innovationsstrategie von Unternehmen beeinflussen. In einem allgemeinen Effizienzlohn-Modell werden Gleichgewichts-Arbeitslosigkeit und Innovation bestimmt.

Die je spezifische Form der Koordination wird dargestellt in ihrer Bedeutung für die Entscheidung von Unternehmen für eine radikale oder eine inkrementelle Innovationsstrategie. Sie wird außerdem auch daraufhin analysiert, wie die Unternehmen auf den gewachsenen Konkurrenzdruck reagieren und welche Entscheidungen sie hinsichtlich ihrer Innovationsstrategie fällen. Eine höhere Arbeitslosigkeit als Auswirkung von Spezialisierungen, ausgelöst durch innovationsbezogene Übergangsprozesse, ist nicht auszuschließen.

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I. Introduction

This paper aims to analyze the relationship between equilibrium unemployment and innovation patterns across different institutional settings. The institutional setting is represented through a set of parameters grasping the mode of coordination prevailing between firms and the intensity of market competition. In particular, two opposite modes of coordination are identified: a fully decentralized market-coordination and a fully centralized coordination (i.e. through business associations). Building on the recent literature on comparative institutional analysis, this distinction allows me to envisage two institutional configurations tentatively corresponding to the modes of coordination respectively prevailing in France and the US, on the one hand, and in Germany and Japan, on the other hand.

The paper addresses the following major questions from a theoretical point of view: does the institutional setting affect firms' innovation choice? How do firms modify their innovation strategy to meet increased competitive pressure on new product markets? Which is the overall effect of these processes on the equilibrium rate of unemployment? To answer these questions, I develop a generalized efficiency wage model bringing together the analysis of the determinants of both unemployment as well as the *nature* of innovation ([1]). In order to do that, I focus on two different forms of R&D, namely knowledge-based research and product-oriented research. Innovation at the firm level is supposed to come from the possibility of increasing profits through product-oriented innovations, while knowledge-based research is provided in external (public-funded) research centers. Starting from this characterization, the paper focuses on the determinants and effects of firm' innovation strategy: the optimal innovation strategy corresponds to the proportion of scholars affected by the firm to product-oriented research, in such a way to maximize anticipated profits. Since firms' evaluation of the overall effects of innovation on profits depends on their capacity to internalize all the indirect externalities of their individual choice, the optimal innovation strategy is affected by the degree and nature of external coordination, that is by the prevailing institutional setting.

In particular, I assume that individual firms' innovation strategy has direct and indirect effects at both the macro and the micro levels: at the micro level, innovation affects the internal structure of the firm, that is the incentive scheme and the efficiency of internal coordination; while at the macro level, innovation may affect products' range and turn-over. In the paper, I assume that centralized coordination improves firms' perception of the indirect effects (both at the micro as well as at the micro level) of their innovation choice. Because of the impact of innovation of their internal structure, when choosing their optimal innovation strategy firms face both an effort determination as well as an internal coordination enhancement problem. Therefore, profits maximization takes place in an efficiency wage framework with knowledge-based innovations playing their role in destroying matches on the labor market. The global equilibrium configuration of the model is defined as the couple (u, z) determining equilibrium unemployment (u) as well as the optimal innovation strategy (z).

The structure of the paper is as follows: I first describe the different existing forms of research ad innovation and the role of the mode of coordination in affecting firms' perception of the externalities of their innovation choice (section II); then I analyze the direct and indirect impacts of innovation on the economic structure, both at the micro and at the macro level (section III); third I derive the optimal innovation choice for firms respectively in a context of fully centralized and fully decentralized market-coordination, and analyze the effects of a change in the intensity of market competition (section IV); finally, I derive the overall equilibrium configuration for the model describing the impact of different forms of innovation on the equilibrium rate of unemployment (section V); in section VI, I present some conclusions concerning the main results delivered by the theoretical analysis.

II. Forms of innovation

II.a Outlook of the model

The central focus in the analysis of innovation and unemployment, which follows, is the opposition between two different forms of innovation: product-oriented versus knowledge-based. Product-oriented research basically consists in developing new products that either add up or substitute to old ones. Quite differently, knowledge-based research is a way to produce new knowledge. The two forms of R&D correspond to very different tasks of research that are likely to be performed and/or funded by different organizations. In particular, I will assume that knowledge-based research is accomplished by public research centers with no production aims. In fact, firms are not willing to bare the risk associated to knowledge-based research (whose benefits are also more difficult to appropriate by the innovating firm) and ultimately invest only in product-oriented research ([2]). In any case, the new knowledge generated through knowledge-based research may then be introduced in the production system through new goods incorporating knowledge' advances. According to Teece' distinction between radical and incremental innovations (see Teece, 1986), new goods can be assumed to be radically new if they require firms to acquire radically new competence in order to produce them (see also Soskice, 1996 on this point). I will assume that this definition applies to the new goods incorporating knowledge' advances: in order to be able to produce this special category of new goods, firms need to bring in new resources, and this will mainly be done by renewing their employment matches (see section *III.a* on this point).

In the following, I will take up an efficiency wage perspective in order to model the firms' maximization problem concerning both the innovation strategy as well as production and employment levels in a context where: *i*) firms' choice is affected by the prevailing institutional setting and *ii*) different forms of innovation have an impact on the structure of workers' incentive (and therefore on workers' effort and internal coordination). The following scheme may help the reader understanding the global structure of the model.

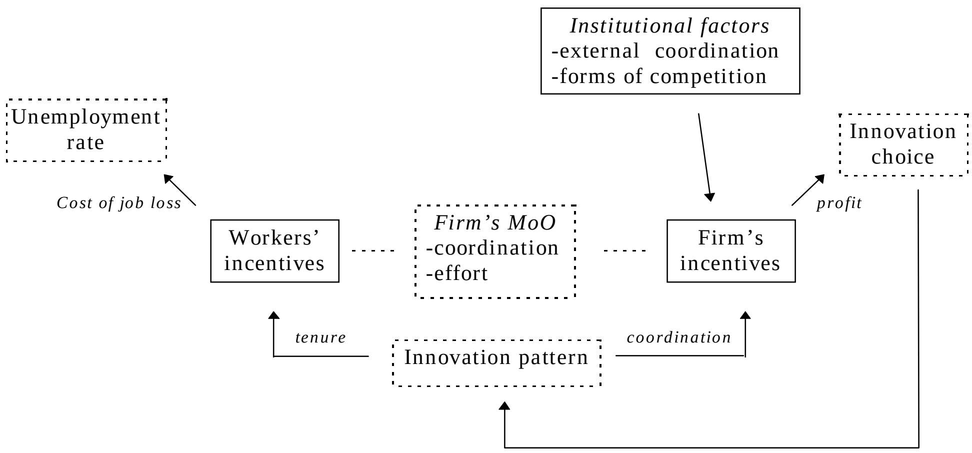

Figure 1

In particular, consider an economy characterized by N firms each one developing a whole range of new products -the equilibrium value of N will eventually be determined by the model. Firms are given a one-period patent for each new product that they develop. Therefore each firm obtains *n* monopolistic market positions, *n* being the (endogenous) number of new goods developed by firm *i*. Then we can think of the N firms as being N different sectors: each sector's dimension is defined by the range of new goods produced by the incumbent firm. At the end of the period, the *n* patents end up, goods become obsolete and start to be sold on purely competitive markets ([3]). The only way to avoid it is for the incumbent firm to renew its products range (this means that firms always have an incentive to embed new knowledge, whenever available, into new products). This can be done by exploiting the results of a knowledge-based innovation, which is only possible if a knowledge-based innovation has occurred during the period (in the next section I will analyze in greater detail the effects of the two forms of innovation on firms' profits).

Assume that the economy is characterized by a number of scientists equal to $H \cdot N$. I will consider that H is given, therefore a fixed number of scientists per sector is given: each firm/sector can use up to H scientists for its product-oriented research. Then, firm *i*'s anticipated profits can be written as:

(1) $$D_t(i) = n\{\int_t^{\infty} \pi_i \exp(-r(\tau-t)) \exp(-(1-\nu)(\tau-t))\, d\tau\} - c(H) - F$$

with: r = interest rate; n = new products; ν = probability of a knowledge-based innovation; π = per period monopolistic profit; $c(H)$ = product-oriented research cost; F = fixed entry cost.

As we can see, anticipated profits depend both on product-oriented as well as on knowledge-based research (through variables n and ν). This will be analyzed in sections *II.b* and *II.c* below. Anticipated profits also depends on per period monopolistic profits (π) that is the profits that each firm can earn on its imperfectly competitive new products markets; as we will see, the level of monopolistic profits will depend on the outcome of profit maximization on the labor market in an efficiency wage framework (see section *III*).

II.b Effects of product and knowledge innovations

In this section I will focus on modeling determinants and effects of the two forms of innovation. As far as the effects of product-oriented and knowledge-based research are concerned, I will assume that:

i) both forms of innovation have a *micro* as well as a *macro* effect: the micro effect concerns the internal structure of the firm, that is workers' effort and coordination; and the macro effect concerns products' range and turn-over;

ii) global resources for innovation are given (and equal to H); therefore, firms determine the final allocation of resources between product-oriented and knowledge-based research by choosing the proportion of scientists that they secure and directly hire. This means that firms' choices have *indirect* effects that affect the amount of research undertaken outside the firm and the overall balance between the two forms of innovation.

In this section I analyze the macro effects of the two forms of innovation; in the next section, I will make it clearer the distinction between direct and indirect effects (and the crucial role of coordination among firms, in this respect) and finally I will move on to the micro effects in section *III*.

From point *i*) we can deduce that both knowledge-based as well as product-oriented innovations have an impact on products structure. In fact, the intensity of product-oriented research defines the firm’s range of new products; while knowledge-based innovation determines the rhythm of products turn-over. No common perspective exists in literature concerning the macro impact of knowledge-based innovations on profits. This can either be considered positive (i.e. in the literature on endogenous growth) or negative (i.e. literature on Schumpeterian endogenous growth: Aghion-Howitt, 1994; Amable, 1995). I will assume that the macro effect of knowledge-based innovation on profit is positive: firms can exploit knowledge’s advances in order to invent radically new products and preserve their monopolistic power on product market (see also Barro and Sala-i-Martin, 1996 for a similar approach). In fact, when a knowledge-based innovation occurs new knowledge is made available which can be embedded by firms into new products. If this is done (and I assume here that this is the case) new products substitute to obsolete ones: substitution is more frequent, more frequent fundamental innovations are. Since we know from point *ii*) that a higher probability of knowledge-based innovation can only be achieved by leaving a larger proportion of scientists to public research centers, firms actually face a trade-off between products’ range and products’ turnover, when choosing the optimal amount of research.

From an overall point of view, depending on which of these two types of research prevails, a priority will be given either to products’ range or to products’ turnover as a preferred pattern of innovation. Since firms only invest in product-oriented research, the prevailing patter of innovation is actually determined by the firm's innovation strategy. In order to understand what the firm's innovation strategy is we have to start modeling the two innovation functions.

To do that, we can follow Amable (1996) and assume that *i*) product-oriented research, because of its nature of «innovation along a given trajectory», allows the firm to develop new products with a reasonable certainty while *ii*) knowledge-based research is subject to randomness and will eventually generate an innovative result with a given probability (ν). This means that the product-oriented innovation function for firm/sector *i* can be specified as follows:

(2) $n_i = n(z_i H)$,

where: n_i = number of new products developed; z_i = proportion of scientists affected to product-oriented R&D; *n()* is a concave function.

The probability of a knowledge-based innovation depends on the *intensity* of knowledge-based research inside the *whole economy*: fundamental innovations are not the product of a sector-specific R&D activity, but rather an economy-wide result affecting all sectors at the same time. The fact that only R&D *intensity* actually matters also means that ν grows up as the proportion (and not the total number) of scientists affected to fundamental innovations increases. This proportion is given by (1-*z*), therefore one obtains:

(3) $\nu = \nu(1\text{-}z)$, $z = (\sum z_j)/\mathrm{N}$, $j = 1, \ldots, \mathrm{N}$,

where ν is assumed to be constant return to scale function, grasping the role of learning processes in knowledge-based research ([4]).The retained specification grasps the trade-off between product-oriented and knowledge-based innovations:

the more intensive is firms' direct R&D, the larger is the proportion of scientists affected to product-oriented research, which means that the proportion of scientists available for knowledge-based research decreases, thus reducing the probability of fundamental innovations to occur.

II.c The « mode of coordination »

Since knowledge-based R&D is undertaken outside the firm, we need to make explicit assumptions on firms' awareness of the externality linking z_i to the probability (ν) of a knowledge-based innovation. In fact, the firm is not necessarily likely to take into consideration the effect of z_i on ν when determining its optimal innovation strategy. In the following, I separately analyze the two cases where firms do take into account this externality as well as the alternative one where they do not. In particular, I will assume that the capacity to internalize externalities is crucially related to the prevailing mode of coordination among firms.

The notion of « mode of coordination » refers to the way firms coordinate each other on the markets (labor markets, or product markets; here I will focus on product markets). If we stick to the two extreme solutions, coordination may be achieved either through purely market mechanisms or through more explicit links, formally and/or informally established. The main interest in opposing these two modes of coordination is that they grasp some aspects of more general distinctions such as the one between different « social systems of innovation » developed by Amable-Barré-Boyer (1997); and the one between coordinated and non-coordinated market economies proposed by Soskice (Soskice, 1990). These two distinctions encompass more general elements relating to the organization of production inside and outside the firm. In their book, Amable, Barré and Boyer present a theoretical and empirical analysis, leading them to describe the social systems of innovation prevailing in France and the US as opposed to the ones prevailing in Japan and Germany: the former would be characterized, among other, by a mechanism of « régulation » mainly through markets, while the latter would rely more on explicit coordination through different kinds of business associations.

In the following, I will build up on this literature and simply distinguish between centralized and decentralized coordination, the latter corresponding to market-coordinated firms and the former to firms connected through a network of explicit links. In more formal terms, this leads us to the opposition between the analytical framework of the purely decentralized economy, on the one hand, and the alternative case of firms acting as a kind of « social planner », on the other. It is straightforward then to expect firms in a centrally coordinated economy to have a macroeconomic perspective, whereas firms connected through market coordination do not. This means that, if we go back to the definition of the probability of a fundamental innovation: $\nu = \nu(1\text{-}z)$, with $z = (\sum z_j)/N$, then firms in a decentralized framework simply consider z as given and do not anticipate the effect of z_i on ν -that is the indirect effects of their innovation strategy on the probability of a fundamental innovation. Quite differently, centrally coordinated firms fully anticipate the above effect, which means that, because of symmetry between firms: $1\text{-}z = 1\text{-}z_i$. This expression is the one that the social planner would consider in order to define the optimal firms' innovation strategy ([5]).

To sum up, the choice of the optimal innovation strategy is likely to depend on the « mode of coordination » prevailing among firms, in the following way (see table 1).

Table 1

Modes of Coordination	
Market-coordinated model	*Centrally-coordinated model*
⇩	⇩
no internalization of externality	*internalization of externality*

We can now go back to the definition of firms' anticipated profits. As we have seen, firm *i* anticipated profits can be written as follows (see equation 1):

$$D_t(i) = n(z_i)\{\int_t^{\infty} \pi_i \exp(-r(\tau\text{-}t)) \exp(-(1\text{-}\nu)(\tau\text{-}t))\, d\tau\} - c(z_i) - F$$

with: r = interest rate; n = new products; ν = probability of a knowledge-based innovation; π = per period monopolistic profit (defined later); $c(z)$ = R&D costs; F = fixed entry cost. Anticipated profits depend both on product-oriented as well as on knowledge-based research (through variables n and ν). In particular, when the probability of a knowledge advance decreases the firm faces a reduction of its own profit expectation due to the lower probability of renewing obsolete products (and obtaining new patents). When the probability that no fundamental innovation occurs $(1\text{-}\nu)$ grows up, expected profits go down and reduces to per period profits if $(1\text{-}\nu) = 1$.

On the basis of the above definition of anticipated profits, the optimal innovation strategy should be designed as a solution to the trade-off between products' range and products' turn-over. The final solution actually depends on whether or not firms anticipate the external effect of their choice (of z_i) on the aggregate probability of a fundamental innovation. However, this reasoning overlooks the fact that each innovation brings about indirect effects on firms structure stemming from the necessary adaptations of firms to modified production conditions. This indirect effects are likely to be incorporated into the determination of monopolistic profits π.

When a knowledge-based innovation occurs, major modifications are produced that eventually affect product structure as well as employment matches. Since obsolete products give way to new goods (as in Amable, 1996) the firm needs to upgrade its resources in order to be able to produce these new goods (see Teece's definition of radical innovations). Previously existing employment matches become inadequate and employment relationships have to be renewed: this determines important consequences on internal variables such as effort. In the same line as this, increasing the products range also produces important effects at the firm level: growing diversification makes internal coordination of production more difficult, thus increasing internal costs and/or determining output waste due to lack of coordination.

The complete set of opposed effects that knowledge-based and product-oriented research respectively determine inside the economy, either at the aggregate or the firm level, are reported thereafter in table 2.

Table 2

Effect on	*Knowledge-based R&D*		*Product-oriented R&D*	
	positive	*negative*	*positive*	*negative*
π_i		Effort e		Coordination h
Anticipated profits	Products turn-over ν		Products range n_i	

In next sections, I will analyze the ways knowledge-based and product-oriented innovations affect monopolistic profits. I will focus in particular on the impact of innovation on firms' organization, both in terms of workers' effort as well as workers' coordination. I will show that different forms of innovation may differently alter firms' incentive schemes, and that this determines major effects on the equilibrium rate of unemployment.

III. Formalizing the firm and the labor market

In this section I focus on the definition of per period monopolistic profit. In order to do that, I will study firm's behavior on the labor market assuming that labor (L) and effort (e) are the only production inputs. Under the assumption of monopolistic product markets, defining the equilibrium configuration of employment and wage will allow me to determine the ex-post amount of profit earned each period by the firm on new products markets. In the following I will drop the index i identifying individual firm variables since the analysis will be entirely carried on at the firm level. Let me consider the decision-making problem faced by firms when determining the optimal level of production and wage. This generally consists in maximizing profits, that is:

(4) $\pi_s = P_s \mathrm{Y}_s - (w + s) \cdot L_s,$

where: Y = production; w = real wage; L_p = hours of work hired; s = real cost of supervising resources per hour of work.

The production function is:

(5) $\mathrm{Y} = h \cdot \mathrm{F}(e \cdot L_p),$

where: h = coordination efficiency; e = effort per hour of work.

Product demand is determined by the following (inverse) demand function:

(6) $P_s = Y_s^{(\alpha-1)}$, $\alpha < 1$,

P_s being the relative price of intermediate product s (in relation to a general price index).

The introduction of s allows me to consider the twofold role played by the central authority respectively in the domain of coordination between production units and control upon work intensity: $s = t + m$, where: t = coordination cost per hour of work; m = monitoring cost per hour of work. To keep things simple I will assume that the unit real cost of both coordination and monitoring resources is equal to one. Contrary to other models, here both workers' ability to coordinate as well as the level of effort are determined by the nature of the incentive scheme implemented by the firm. And the nature of this incentive scheme is conditioned by two crucial factors: innovation patterns and the internal organizational structure of the firm. Let me make this point clear, starting by an explicit modeling of the effort and coordination functions ([6]).

III.a Workers' effort and the labor market

I take up here the efficiency wage approach developed by S. Bowles (see Bowles, 1985). In his contribution, the author applies workers' utility maximization to show that an increase in workers' effort can be obtained mainly in tow ways:

- through "direct monitoring" over workers (m);
- through workers' "cost of job loss" (w_C).

Building on this result, I will adopt a specification of the effort function such as: e = effort per hour of work = $e(w_C, m)$ with: $\partial e/\partial w_C>0$, $\partial e/\partial m>0$. In particular, I will use throughout an explicit functional form in order to make it easier to interpret the model's results, that is:

(7) $e(w_c,m) = w_c^{a} \cdot m^{b}$.

This formulation allows the consideration of the complementary role of the two control devices: no monitoring incentive is possible if there is no cost in loosing his job, conversely no wage incentive can succeed if there is no direct control on effort intensity.

As far as the cost of job loss is concerned, following Bowles I define it as the income loss a worker incurs when he looses his job. Therefore, to evaluate workers' cost of job loss I need to define both their current income and the alternative income they can expect to earn in case they are fired. Let me call these two incomes, respectively, w_{cu} and w_d. Then, the cost of job loss is: $w_c = w_{cu} - w_d$.

I will assume that workers are assigned to jobs at the beginning of each period, that is after a knowledge-based innovation has occurred. But then, knowledge-based research can produce an innovation with a probability ν. Since this innovation is assumed to destroy any previously establish match between workers and firms, workers will take into account the possibility of loosing their jobs because of innovation (that is, independently of their effort performance) when they evaluate their current income. This leads us to: $w_{cu} = (1-\nu)\, w + \nu\, w_d$, where: w= real wage.

The cost of job loss is then equal to:

(8) $w_c = (1-\nu)\,(w-w_d)$,

thus grasping the role of knowledge-based innovations in reducing the incentive pressure determined by monitoring through the firing threat ([7]). The rationale of this result is as follows: when the probability of a fundamental innovation grows up, high effort can no longer guarantees workers their jobs and this reduces workers' incentive to work harder.

The definition of the alternative income (in case of firing) depends on the process of search on the labor market. The final issue of this process is crucially affected by global job opportunities (grasped by the unemployment rate, u) and specific workers' characteristics (namely, transferability of competence). Here, I will assume that workers have perfectly transferable competence and I will focus only on the former factor ([8]). Then the final expression of the alternative income (w_d) is: $w_d = (1-u)\, w_v + u\, \underline{w}$, with: w_v = alternative market wage; $\underline{w}$ = unemployment benefits; u = unemployment rate.

Once defined the expression of the alternative income w_d we can easily deduce the cost of job loss w_c. As we can see, the probability of knowledge-based innovations enters the definition of the cost of job loss and therefore affects firm's incentive scheme: a higher intensity in knowledge-based R&D is likely to lead to a weakening of firms' capacity to obtain a high level of workers' effort.

III.b Workers' coordination inside the firm

Internal coordination is the product of the ability of workers and/or hierarchy to correctly organize different production units. This allows the firm to avoid wasteful actions thus reducing possible output loss: $Y_s = h \cdot F_s(e \cdot L)$, where: h = coordination efficiency.

In the following, I will analyze the problem of internal coordination in the context of multi-products firms. In this context, the firm has to allocate optimally its resources between two different coordination tasks: coordination between workers and between product divisions. Let me assume that each firm is endowed with $n\cdot\tilde{t}$ units of coordination resources per hour of work; then a cost $(n\cdot\tilde{t}\cdot L)$ should be added to production costs due to extra-resources hired for coordination. Since a multi-products firm requires two different coordination tasks, part of the overall coordination resources $n\tilde{t}$ has to be transferred from workers' coordination (h_w) to product divisions' coordination (h_d).

I will assume that in order to implement product divisions coordination an amount β of « coordination activities » is to be realized which demands a quantity $\beta\cdot(n\cdot\tilde{t})^{\delta}$ of the overall firm's coordination resources. the remaining coordination resources are directly used to improve coordination among workers. Let me define: $h = h_w\cdot h_d$. Then: $h_d = \beta^{\gamma}$, $h_w = (n\cdot\tilde{t} - \beta\cdot(n\cdot\tilde{t})^{\delta})^{1-\gamma}$.

The proportion (β) of transferred resources out of total resources ($n\tilde{t}$) is given by the resolution of the following maximization problem:

$$\max_{\beta}\ Y = \beta^{\gamma}\cdot(n\cdot\tilde{t} - \beta\cdot(n\cdot\tilde{t})^{\delta})^{1-\gamma}\cdot e(w_c, m)\cdot L$$

Y being the level of production.

The above problem can be solved one step before the complete resolution of the model since results do not depends on the actual level of production. Solution to the maximization problem is given by: $\partial Y/\partial\beta = 0$, which leads to:

(9) $$h^* = (1-\gamma)^{1-\gamma}\cdot\left(\frac{1}{n\cdot\tilde{t}}\right)^{\gamma\delta-1}, \qquad \varepsilon = \gamma\delta\text{-}1 > 0 \ \ ([9]),$$

that establishes a negative effect of products' diversification on coordination ability. This is a common result in literature on firms organization. In fact, in static frameworks, the complexity of handling organizational issues is considered a major determinant of increasing unitary costs at high production scale. On the other side, in more dynamic approaches, it is explicitly admitted that a main limit to enlarging products range is the connected lost in the efficiency of internal coordination ([10]).

We have now defined all the components of firms' production function. In the following, I will proceed to the resolution of the model under the assumption that firms maximize their profits on the labor market given their monopolistic position on (new) products markets.

IV. Patterns of innovation

In this section, I present the general solution to the model and analyze the results concerning the optimal innovation strategy (z^*) in different institutional settings (namely the mode of coordination and product market competition); in the next section, I will move on to the impact of different innovation patterns on the equilibrium rate of innovation.

IV.a Equilibrium conditions

The firm has to choose: monitoring resources, wage, employment and innovation strategy (respectively variables m, w, L and z) in order to maximize its profits. Given that research allows the firm to earn monopolistic profits on new goods markets, the present value of the future flow of profits is evaluated as follows (see equation 1):

$$D_t(i) = n(z_i)\{\int_t^{\infty} \pi_i \exp(-r(\tau-t)) \exp(-(1-\nu)(\tau-t))\, d\tau\} - c(z_i) - F.$$

In the following I will avoid using the index i for individual firm variables in order to simplify notation. Of course, whenever this could cause a misunderstanding, I will clearly state variables' status. Therefore, profits maximization takes the following form:

$$\max_{m,\, L,\, w,\, z} \quad n \cdot \int_t^{\infty} \pi \exp[-(r-\nu+1)(\tau-t)]\, d\tau - c(z) - F$$

where $c(z)$ is the cost to the firm of scientists hired for product-oriented research. I will assume $c(z)$ to be a linear function, such that:

(10) $\quad c(z) = w_S \cdot z \cdot H,$

w_S being the real wage of scientists. Scientists who are not hired by firms are automatically affected to knowledge-based research in the public sector where they are paid a wage ϖ which is assumed given. Therefore, the ex-post wage of scientists is such that: $w_{S\,(\text{ex-post})} = \varpi$.

The expression of profits' present value D_t can be rewritten, by solving out the integral, in following form:

(11) $\quad D_t = \dfrac{n}{1+r-\nu} \cdot \pi - w_S \cdot z \cdot H - F.$

In order to simplify notation let me define the function:

(12) $\quad G(z) = \dfrac{n}{1+r-\nu},$

whose sign is determined by the composed effect of the two innovation functions, n and ν (see below). Then, in order to solve the firms' maximization problem we simply have to substitute the demand function for P_s and the effort and coordination functions for Y_s into profit's expression, and then calculate the first derivatives of profits in relation to the four control variables.

Considering that the demand function is: $P_s = Y_s^{(\alpha-1)}$, $\alpha<1$, and that per period profits for product s are: $\pi_s = P_s Y_s - (w + \tilde{t} + m)\cdot Ls$, where: $Y_s = h\cdot e\cdot Ls$ is the production function, the maximization leads us to the following first-order conditions:

(13.*a*) $\partial\pi/\partial m = 0 \Rightarrow P_s\cdot h\cdot e'_m = 1/\alpha$,

.*b* $\partial\pi/\partial w = 0 \Rightarrow P_s\cdot h\cdot e'_w = 1/\alpha$,

.*c* $\partial\pi/\partial L = 0 \Rightarrow \alpha\cdot P_s\cdot h\cdot e = w + \tilde{t} + m$.

.*d* $\partial\pi/\partial z = 0 \Rightarrow G'_z\cdot\pi + G(z)\cdot\alpha\cdot P_s\cdot(e'_z\cdot h\cdot L + e\cdot h'_z\cdot L) - \varpi\cdot H = 0$,

since $w_{S\,(\text{ex-post})} = \varpi$.

Considering that, at the equilibrium, anticipated profits must be equal to zero in order to prevent firms' entry, a zero-profit condition must be added to first-order conditions above. Imposing the zero-profit condition we obtain:

(14) $$\pi_{\text{ex-post}} = \frac{F + \varpi\cdot z\cdot H}{G(z)}.$$

Considering also that equilibrium on the labor market necessarily implies:

(15) $(1-u)\cdot LF = N\cdot L$,

where LF = total labor force, the model is closed and can simply be solved through subsequent substitutions.

On the basis of the set of conditions above we can determine the equilibrium configuration of the model and study the interaction between patterns of innovation and the equilibrium rate of unemployment. The equilibrium configuration will be defined as the couple (z^*, u^*). The first step towards a complete resolution of the model is therefore to determine the optimal innovation strategy z^*. Let me start by substituting condition (3) and the zero-profit condition into condition (4). From condition (3) we know that: $\alpha \cdot P_s \cdot L = \frac{\alpha}{1-\alpha} \cdot \frac{\pi}{e \cdot h}$, then substituting this and (5) into condition (4) I obtain:

$$15.d' \quad (F + \varpi z H) \cdot \left[\frac{G'_z}{G(z)} \cdot (1-\alpha) + \alpha \cdot \left(\frac{e'_z}{e} + \frac{h'_z}{h} \right) \right] - (1-\alpha) \cdot \varpi H = 0$$

In condition (4′) we can distinguish two different effects of innovation on profits. The direct effect (first element in square brackets) is given by the derivative of function *G(z)* and evaluates the effect of innovation on both products' range and turn-over. The indirect effect (second element in square brackets) is instead given by the impact of innovation on both internal coordination and effort. As we will see, these two effects combine in a different way according to the prevailing mode of coordination (see below, table 4).

IV.b Optimal innovation strategy

In order to simplify notations and make the solution clearer, I need to assume a specific functional form for the two innovation functions. As we have seen (*section II*), the probability of each type of innovation grows up as the proportion of scientists affected to related research increases: $n_i = n(z_i H)$,

$\nu = \nu(1\text{-}z)$.

Since ν is assumed to be a constant return to scale function, I will simply consider that the specification of the fundamental innovation probability has the following form: $\nu = 1\text{-}z = 1\text{-}(\sum z_j)/N$, N being the number of sectors in the economy. Product-based innovations are instead the result of a decreasing return R&D activity, then we can simply assume that: $n_i = (z_i H)^c$, $c < 1$.

Once defined the innovation functions, in order to determine the sign of the function *G(z)*, I still need to incorporate the assumptions on firms' awareness of the externality linking z_i to the probability of knowledge-based innovations ν (see table 3 below).

As we have seen, the mode of coordination affects firms' evaluation of the impact of z_i on anticipated profits. In fact, in *section II* we have shown that the probability ν of a fundamental innovation depends on the *aggregate* proportion of scientists affected to knowledge-based research (z). Market-coordinated firms simply consider z as given and do not anticipate the effect of z_i on ν. Conversely, in the centrally-coordinated model, firms actually act as a kind of « social planner ». Because of symmetry between sectors (firms), the expression for ν is then equal to: $1\text{-}z = 1\text{-}z_i$. In the following, I will analyze separately the case where firms take into account the externality and the alternative one (i.e., the centrally-coordinated versus market-coordinated model).

Table 3

	Institutional settings	
	Centrally- versus market-coordinated model	Intensity of products markets competition
Parameters	Externality on ν $\nu = 1\text{-}\ z_i$ $\qquad \nu = \overline{\nu}$	α

In table 4 below, I list all of the relevant effects of z_i on anticipated profits, indicating whether they are taken into consideration by firms (yes) or not (no), depending on the prevailing mode of coordination.

Table 4

	Knowledge-based R&D		*Product-oriented R&D*	
	positive	*negative*	*positive*	*negative*
	Products turn-over ν	Effort e	Products range n_i	Internal Coordination h
Market-coordination	no	no	yes	yes
Centralized coordination	yes	yes	yes	yes

From previous assumptions, summed up in the above table 4, we can deduce that the specification of the different elements in equation 15.d' above is as follows:

$$\frac{G'_z}{G(z)} = \begin{cases} -(1-c)/z & \textit{centrally coordinated environment} \\ c/z & \textit{market-coordinated environment} \end{cases}$$

$$\frac{e'_z}{e} = \begin{cases} a/z & \textit{centrally coordinated environment} \\ 0 & \textit{market-coordinated environment} \end{cases}$$

$$\frac{h'_z}{h} = -c\varepsilon/z \qquad \textit{both}$$

We can now proceed to the identification of the equilibrium patterns of innovation in two alternative cases of a centrally coordinated model and of a market-coordinated model. Let me consider first the case of a centrally-coordinated (CC) model. The firm has a macroeconomic perspective and takes into account the externality (on ν) coming form its choice of z. Assuming that an interior solution exists ([11]) and taking for simplicity a zero interest rate value (r=0), the equilibrium value of the firm's innovation strategy is:

$$(17) \qquad z_{CC}* = \left(\frac{\alpha\cdot(1-c(\varepsilon+1)+a)+c-1}{2-c-\alpha\cdot(2-c(\varepsilon+1)+a)}\right)\cdot\frac{F}{\varpi H}\ .$$

In the alternative case of a market-coordinated (MC) model, we know that the firm has no macroeconomic perspective and therefore it does not take into account the externality (on ν) coming form its choice of z. Once again we assume that the interest rate r is equal to zero, and we apply the same method as before in order to solve the model.

Considering that the impact of z on effort via ν is overlooked because of the hypothesis of a market-coordinated environment, the direct effect of innovation on profits (i.e. through the function $G(z)$) is now positive while the indirect effect (i.e. through internal organization) consists of one single factor, that is the impact of innovation on coordination, the impact on effort being neglected together with the externality on ν.

The optimal innovation strategy under this hypothesis is therefore ([12]):

$$(17) \qquad z_{MC}* = \left(c\cdot\frac{1-\alpha\cdot(1+\varepsilon)}{1-c+\alpha\cdot(c(\varepsilon+1))}\right)\cdot\frac{F}{\varpi H}$$

These results show that the innovation strategy followed by firms is affected by the prevailing institutional configuration, that is the value of parameters defining the mode of coordination between firms and the intensity of product markets competition. It is therefore possible to develop a comparative analysis of innovation patterns undertaken by firms under varying institutional conditions. In particular, it is interesting to analyze possible differences in firms' responses, in terms of innovation, to increasing market competition. In fact, when market competition goes up, firms are faced with harder market conditions and must therefore try to face them by modifying their innovation strategy in order to improve profits. Form the analysis above we can easily see that:

$$\partial z_{CC}^*/\partial\alpha > 0,$$

$$\partial z_{MC}^*/\partial\alpha < 0.$$

This result shows that when α grows up (that is, when the product market becomes more competitive) the optimal z value for the centrally-coordinated model increases while it decreases in the alternative case of a market-coordinated model. This means that in a centrally-coordinated environment firms try and face market competition by increasing their own R&D activity, while market-coordinated firms prefer to allow for an increase in fundamental innovations by reducing their own innovation activity (z). Therefore, increasing market competition actually determines a diversification in the trajectories of innovation followed by firms in the two different institutional settings. To sum up, we should say that a centrally-coordinated environment is more favorable to product-oriented innovation, while market-coordinated firms are more likely to follow a pattern of innovation focused on knowledge-based R&D.

Given our previous results, we should expect that product-oriented R&D's leadership ultimately shifts to firms acting in centrally-coordinated institutional models when products markets become more competitive (i.e. α increases). This result seems to be coherent with stylized facts from comparative analyses of patterns of innovation in countries such as Japan, Germany, US and France. These analyses generally tell us that the first two countries undergo a more product-oriented pattern of innovation than do France and the US, with large products ranges combined with slow products turn-over. Since both Germany and Japan can be characterized as centrally-coordinated models, the increasingly good performance of these two countries in product-oriented innovations could be interpreted as the result of a their reactions to changing markets conditions: a « global » increase in the intensity of market competition leading centrally-coordinated countries (Germany and Japan) to increase product-oriented research, while pushing market-coordinated countries (i.e. France and the US) to invest in more knowledge-based R&D. This could be one reason for the ongoing process of differentiation in national trajectories of innovation observed by some authors (se Soskice, 1996 and Amable-Barré-Boyer, 1997).

Once defined the optimal value of the firm's innovation strategy (*z*), we can move on to the definition of the associated equilibrium rate of unemployment associated. That will be done in the next section of the paper.

V. Global equilibrium configuration

In this section, I will show how one can determine the equilibrium rate of unemployment associated with each of the two patterns of innovation disentangled above. My main interest is to present results concerning the expected relationship between unemployment and innovation, that is the shape of what I will call the *unemployment curve*. In order to do that, I have to go back to first-order conditions presented in *section IV* above, in order to solve the whole model. Then, the equilibrium number of firms/sectors (variable N) will in turn be determined too, due to the condition of equilibrium on the labor market: $(1-u^*)\cdot LF = \mathrm{N}\cdot L^*$, where u^* is the equilibrium rate of unemployment and LF the total labor force.

V.a The unemployment curve

To determine the equilibrium rate of unemployment, let me first go back to the four first-order conditions set out in the equation 13 above ([13]). Combining *(a)* and *(b)* we can determine the firm's optimal incentive scheme (that is, the equilibrium ratio of monitoring and the cost of job loss); then we can use this result to substitute for monitoring into conditions *(b)* and *(c)*; finally, by combining conditions *(b)* and *(c)* we determine the equilibrium relationship between wage and the unemployment rate, i.e. what is generally called the *wage curve* (hereafter, $w(u)$). In order to define the equilibrium rate of unemployment we just have to combine the wage curve and the constant unit cost's condition (*b*). This gives us the first condition for price determination, that is the optimal price coming from the cost mark-up behavior of firms ([14]):

(18) $P^*_S = 1/(\alpha\cdot h\cdot e'_w)$, with $w^* = w(u)$, $\quad w'_u < 0$.

Then we have to consider this together with the second condition for price determination that is coming from the zero-profit condition:

(19) $$P^*_s = \left[\frac{(1-\alpha)\cdot G(z)}{F+\varpi zH}\right]^{(1-\alpha)/\alpha}.$$

If we equate the two price conditions above, and substitute the wage curve w^* for w, we finally obtain an equilibrium relationship between the unemployment rate and the innovation strategy z (that I will call the *unemployment curve*):

$$(20) \qquad \mathrm{K}\cdot(zH)^{-c_{\varepsilon}}\cdot w_{\mathrm{c}}^{-(1-a-b)} - \frac{1}{\alpha}\cdot\left[\frac{F+\varpi zH}{(1-\alpha)\cdot G(z)}\right]^{(1-\alpha)/\alpha} = C(w(u), z) = 0,$$

where K is a given constant.

It is straightforward to note that the sign of the unemployment curve is given by: $\frac{\partial u}{\partial z} = -\frac{\partial C/\partial z}{\partial C/\partial u}$. One can easily show that $C'_u > 0$, while concerning C'_z two opposite effects are at work and it is therefore difficult to conclude about its sign ([15]). These two effects come from the two price equations that combine to determine the equilibrium rate of unemployment. The first one (eq. 18), coming from firms' pricing behavior, tells us that an increase in product-oriented research (variable z) determines a reduction of unitary production costs; the second one (eq. 19), says that an increase of z produces an increase of anticipated profits and therefore a reduction of the price level compatible with the zero-profit condition. If the first effect dominates, the unemployment rate should decrease when z increases, in order to bring up again unitary cost through wage pressure. The opposite holds when the second effect dominated. The result of the combination of these two factors mostly depends on the level of z and u. One can show that $C'_z > 0$ (and the mark-up effect dominates) when unemployment is high and z low (which means that $du/dz < 0$), while $C'_z < 0$ (and the « zero-profit condition » effect dominates) when unemployment is low and z high (which means that $du/dz > 0$). We can thus represent the unemployment curve as an U-shaped curve as in figure 1 below.

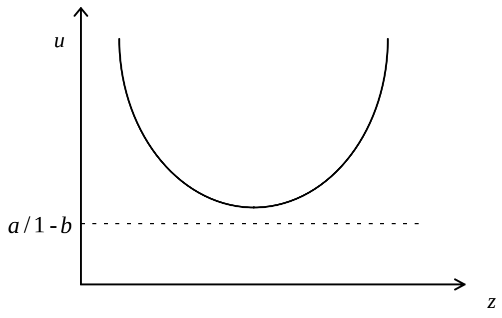

Figure 1

The figure shows that, when z increases from low to high values, unemployment first reduces and then starts to increases too. The same thing happens when z decreases from high to low values. The two cases are good representations of the process of diverging specialization of the centrally coordinated versus the market-coordinated model in respectively product-oriented versus knowledge-based R&D. In both cases, then, specialization in a new form of innovation has, first, a positive impact on unemployment since it allows to strengthen investments in an emerging field of innovation, at the same time subtracting them from the established one. However, when the new pattern of innovation is established, the impact of innovation on unemployment is likely to become negative. This result is coherent with the main result in Aghion and Howitt’s paper showing that the employment impact of growth is likely to become negative at high growth rates. Besides that, the model shows that what actually matter in determining adverse effects of innovation on employment is a strong specialization in an established pattern of innovation.

V.b The equilibrium rate of unemployment

Considering both the optimal innovation strategy (derived in *section IV*) as well as the unemployment curve presented above, the global equilibrium configuration can easily be determined. In particular, it is interesting to analyze the effect on structural unemployment brought about by the process of specialization in national patterns of innovation (described in the previous sections). In fact, increasing competitive pressure is likely to have two main effects in my model:

- the first one is the standard direct effect of α on firms pricing behavior ([16]): increasing competitive pressure corrects firms' imperfectly competitive behavior and therefore reduces the mark up over costs. This is generally expected to have a positive impact on structural unemployment via a downward shift of the unemployment curve (and this is actually the case here under some parametric assumptions);
- the second effect is an indirect one, working via the modification of firms' innovation strategies; increasing specialization is likely to push the economic systems toward one of the extremities of the unemployment curve and therefore has a negative impact on structural unemployment.

The final result in terms of unemployment evolution ultimately depends on the combination of these two effects, and therefore on the relative impact of competitive pressure on, respectively, pricing behavior and innovation strategies.

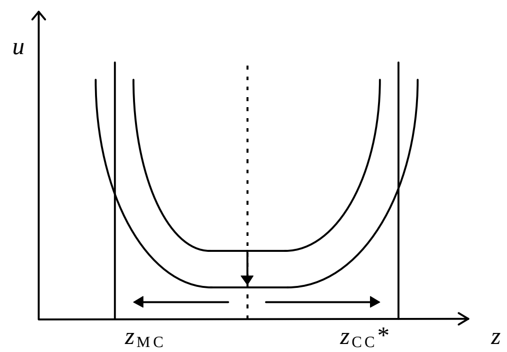

Figure 2

The above results could actually help explaining the long-run evolution of the equilibrium rate of unemployment in developed countries such as Germany vs. Japan, and France vs. the US. In particular, the general overtime increase in the level of structural unemployment could be the result of a long-run macroeconomic evolution (i.e., increase in the intensity of markets' competition) reinforcing cross-country specialization in well-established patterns of innovation: respectively, product-oriented R&D for the centrally coordinated model and knowledge-based research for the market-coordinated model). If the counter-balancing effect acting via firms' pricing behavior is not strong enough, then this process ultimately pushes the economic systems towards one of the two extremities of the U-shaped unemployment curve above.

VI. Conclusion

In the paper, a generalized efficiency wage model is proposed to analyze firms' choice about employment and innovation as conditioned by a (given) set of institutional parameters. More precisely, two institutional configurations have been compared: one where firms act in a centralized coordination framework; a second one where firms act in a decentralized market-coordination framework. This distinction is assumed to grasp the opposed institutional models characterizing the Japanese and German economies as compared to France and the US.

Under some parametric conditions, it is shown that different equilibrium strategies of innovation emerges according to the prevailing institutional configuration. Building on this result, the level of the associated equilibrium rate of unemployment is derived. This allows me to characterize differences in national trajectories of innovation and employment performances.

I subsequently study the effect on the above national trajectories of a change in the intensity of products market competition. I show that this leads the firms in a centrally coordinated framework to reinforce the product-oriented nature of their research, while firms in the market-coordinated configuration are instead driven to increase the proportion of knowledge-based R&D. This divergent specialization, as far as the innovation activities are concerned, also has an impact on the equilibrium rate of unemployment that can be described through an U-shaped curve linking the equilibrium unemployment rate to the optimal innovation strategy.

The model can therefore help us understanding how institutional settings may account for the persistence of cross-country differences in unemployment and innovation patterns and also explain divergent national responses in relation to an alike modification in the intensity of competition on products markets. The above results deliver us a picture stressing the institutionally determined nature of both the equilibrium rate of unemployment as well as innovation patterns. This may allow us to throw some light on the structural determinants of national patterns of innovation. At the same time, the model helps understanding the possible interactions between different forms of innovation and the level of the equilibrium rate of unemployment.

Appendix

1) ***Solving the internal coordination problem***.

$\partial Y/\partial\beta = 0 \Rightarrow \gamma\cdot\beta^{(\gamma-1)}\cdot(n\cdot\tilde{t} - \beta\cdot(n\cdot\tilde{t})^{\delta})^{1-\gamma} - \beta^{\gamma}\cdot(1-\gamma)\cdot(n\cdot\tilde{t} - \beta\cdot(n\cdot\tilde{t})^{\delta})^{-\gamma}\cdot(n\cdot\tilde{t})^{\delta} =$

0,

that gives us the result: $\beta^* = \gamma\left(\frac{1}{n\cdot\tilde{t}}\right)^{\delta-1}$,

and: $Y = \gamma^{\gamma}(1-\gamma)^{(1-\gamma)}\left(\frac{1}{n\cdot\tilde{t}}\right)^{\gamma\delta-1} e(w_c, m)\cdot L$.

2) ***Optimal innovation strategy: condition for interior solutions***.

The centrally-coordinated firms:

conditions for an internal solution		
$z^* > 0$	$\Leftrightarrow$	$a > c\varepsilon$
		$\alpha_0 < \alpha < \alpha_1$
$z^* < 1$	$\Leftrightarrow$	$\alpha < \alpha_2$

where α_0, α_1, α_2, are endogenously determined constants:

$\alpha_0 = (1-c)/[1-c(\varepsilon+1)+a]$,

$\alpha_1 = (2-c)/[2-c(\varepsilon+1)+a]$,

$\alpha_2 = (3-2c)/[3-2c(\varepsilon+1)+2a]$.

The market-coordinated firms:

conditions for an internal solution		
$z^* > 0$	$\Leftrightarrow$	$\alpha < 1/(\varepsilon+1)$
$z^* < 1$	$\Leftrightarrow$	$c > 1/2$
		$\alpha < (2c-1)/[2c(\varepsilon+1)-1]$

3) ***Determining equilibrium unemployment***.

Consider the four first-order conditions below:

.*a* $\partial\pi/\partial m = 0 \Rightarrow P_s\cdot h\cdot e'_m = 1/\alpha$,

.*b* $\partial\pi/\partial w = 0 \Rightarrow P_S \cdot h \cdot e'_w = 1/\alpha$,

.*c* $\partial\pi/\partial L = 0 \Rightarrow \alpha \cdot P_S \cdot h \cdot e = w + \tilde{t} + m$.

.*d* $\partial\pi/\partial z = 0 \Rightarrow G'_z \cdot \pi + G(z) \cdot \alpha \cdot P_S \cdot (e'_z \cdot h \cdot L + e \cdot h'_z \cdot L) - \varpi \cdot H = 0$.

Combining *(a)* and *(b)* we can determine the firm's optimal incentive scheme (that is, the equilibrium ratio of monitoring and the cost of job loss); then we can use this result to substitute for monitoring into conditions *(b)* and *(c)*; finally, by combining conditions *(b)* and *(c)* we determine the equilibrium relationship between wage and the unemployment rate, i.e. what is generally called the *wage curve*:

$$w^* = \frac{a \cdot \tilde{t} + (1-\nu) \cdot (1-b) \cdot u \cdot \underline{w}}{(1-\nu) \cdot (1-b) \cdot u - a}, \qquad \text{with } \frac{\partial w^*}{\partial u} < 0.$$

Note that, in order for wages to be positive and avoid wage explosion, a minimum unemployment rate ($u_{\min}$) exists such that:

$u > u_{\min} = a \,/\, (1\text{-}b)(1\text{-}\nu)$.

The minimum unemployment rate increases when the probability of a fundamental innovation grows up: this is linked to the incentive-reducing role of the knowledge-based R&D's intensity.

In order to define the equilibrium rate of unemployment we just have to combine the wage curve and the constant unit cost's condition that is (from condition *(b)* above):

$h \cdot e'_m = h \cdot e'_w = 1/(\alpha\, P_S)$,

$1/e'_w = (w + \tilde{t} + m) \,/\, e \qquad \Rightarrow \qquad P^*_S = (1/\alpha) \cdot [(w + \tilde{t} + m)/he] = 1/(\alpha \cdot h \cdot e'_w)$

$w^* = w(u), \qquad w'_u < 0.$

Then, to obtain the equation for the unemployment curve, we have to consider the condition above together with the second condition for price determination that comes from the zero-profit condition, that is the following:

$$P*_s = \left[\frac{(1-\alpha)\cdot G(z)}{F+\varpi zH}\right]^{(1-\alpha)/\alpha}.$$

4) ***The slope of the unemployment curve***.

In order to determine the slope of the unemployment curve, we have to know the sign of the two partial derivatives: C'_u and C'_z. Concerning C'_u one can easily see that:

$$u\uparrow \quad \Rightarrow \quad w\downarrow \quad \Rightarrow \quad w_c\downarrow \qquad\qquad \Rightarrow \quad C'_u > 0,$$

which allows me to determine the sign of the partial derivative of C with respect to the unemployment variable (u).

However, concerning the derivative of C with respect to z, we must note that:

$$z\uparrow \quad \Rightarrow \quad (zH)^{-c_\varepsilon}\cdot w_c^{-(1-a-b)} \uparrow,$$

$$\frac{1}{\alpha}\cdot\left[\frac{F+\varpi zH}{(1-\alpha)\cdot G(z)}\right]^{(1-\alpha)/\alpha} \uparrow,$$

that is, two opposite effects are at work and it is therefore difficult to conclude about the sign of C'_z. The result of the combination of these two factors mostly depends on the level of z and u. In fact, resolving equation (20) with respect to the variable z, one can see that:

$$C'_z \approx \mathrm{R}\cdot u - \mathrm{d}\cdot \mathrm{z}^{(\mathrm{d}-1)}\cdot(1+\mathrm{z})^{(1-\alpha)/\alpha}\cdot(z\cdot(1-b)\cdot u-a)^{(a+b)} - \frac{1-\alpha}{\alpha}\cdot \mathrm{z}^{\mathrm{d}}\cdot(1+\mathrm{z})^{(1-2\alpha)/\alpha}\cdot(z\cdot(1-b)\cdot u-a)^{(a+b)},$$

$\mathrm{R}=(1-b)\cdot(1-a-b)$ and $\mathrm{d}>0$ being constant.

Therefore, we can reasonably assume that $C'_z > 0$ (and the mark-up effect dominates) when unemployment is high and z low (which means that du/dz < 0), while $C'_z < 0$ (and the « zero-profit condition » effect dominates) when unemployment is low and z high (which means that du/dz > 0).

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Footnotes

[1] The theory of growth has rarely dealt with this subject. Aghion and Howitt (1994) propose a model where innovation is the source of growth and has opposite direct/indirect effects on unemployment; Boyer (1988) proposes a model where accumulation and technological change jointly determine employment evolution.

[2] A second reason for that is that I only focus on a stable population of firms, and therefore I d not treat the phenomenon of start-up. Generally speaking, one main interest of incumbent firms is to strengthen their market positions (i.e. through product improvements) rather then to create entirely new markets.

[3] This assumption actually has some important consequences. In fact, is means that the economy will fluctuate across different « regimes of competition », that is monopoly and perfect competition. Monopoly prevails when a fundamental innovation occurs and firms exploit it through radically new products; perfect competition follows then when these products become obsolete. Of course this affects the determination of the equilibrium rate of unemployment for the economy since it will fluctuate too according to regime' changes. However this is easily incorporated into the model for it simply determines a *temporary* shift of the *whole economy* from one equilibrium to another (therefore fundamental innovations affect the rhythm of economic cycles). Since I have already developed a full analysis of the equilibrium rate of unemployment in perfectly competitive markets (see Gatti, 1998), I will not treat this topic here.

[4] This is just a simplifying assumption taken up in order to avoid introducing too many parameters into the analysis. If we consider that knowledge-based research is a decreasing return to scale activity too, then a sufficient condition for subsequent results to hold is knowledge-based research coefficient to be larger then the one for product-oriented innovation.

[5] This allows me to avoid addressing the question of cross-sector strategically behavior, that is not my main focus here.

[6] In the following sub-sections, I present a formal micro-institutional analysis building on a framework developed in a previous paper (see Gatti, 1998).

[7] The same assumption is taken up by other authors. Saint-Paul (1996, p. 3) for instance assumes that workers with higher (intrinsic) turn-over are characterized by a lower cost of job loss. The same hypothesis can be found in OCDE (1997).

[8] In a previous paper (Gatti, 1998) I develop a more complete analysis where workers competence are assumed to be only imperfectly transferable. For the sake of simplicity I do not take up this issue here. Since innovation patterns are likely to be one major determinant of the intensity of competence transferability, this issue would lead me to treat the cumulative link between innovation and competence which is not my main focus here.

[9] See the appendix (point 1) for more details. This is not a too strong hypothesis since, $(nt)^{\delta}$ being a cost and therefore a generally convex function, δ can easily be assumed to be greater than 1. Then, it is sufficient to fixe a values' range for γ such that this parameter turns out not be bigger than $1/\delta$.

[10] This perspective underlines the role of organizational resources as the main determinant of a firm's capacity to expand. In this sense, organizational resources can be seen as the only long-run constraint faced by firms when they try to grow through diversification (see also Penrose, 1959 on this point).

[11] Necessary restrictions on the parameter, for the interior solution to exist, are set out in the appendix (point2).

[12] Necessary restrictions on the parameter, for the interior solution to exist, are set out in the appendix (point2).

[13] The entire procedure is detailed in the appendix (point 3).

[14] The entire procedure is detailed in the appendix (point 3).

[15] The entire procedure is detailed in the appendix (point 3).

[16] One can see Layard at al. (1991) on this point, chap. 6 and 7 in particular.

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